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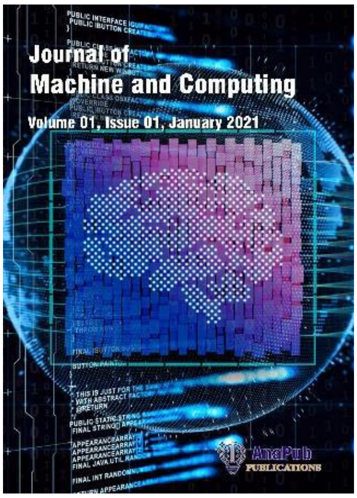
Processing Adaptive Data Insertion in Steganography



Abdelkader boudaoud, Naima hadj said and Hana Ali-Pacha

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Processing Adaptive data insertion in steganography

[1]Abdelkader boudaoud, [2]naima hadj said,[3]Hana Ali-Pacha

[1,2]*Laboratory of coding and security of information, Department of Mathematics and Computer Science , University of Sciences and Technology of Oran Mohamed Boudiaf USTO-MB B.P. 1505, El Mnaouar – Bir el Djir, Oran Algeria*
[3]*Quartz Laboratory, École Catholique d'Arts et Métiers-École d'Électricité, de Production et desMéthodes Industrielles (ECAM-EPMI), 95092 CergyPontoise, France.*

[1]*aek.boudaoud@cu-elbayadh.dz,*[2] *naima.hadjsaid@univ-usto.dz,* [3]*h.ali-pacha@ecam-epmi.com*

Abstract

In an era of rapidly evolving communication methods, the exchange of sensitive information— such as personal data, financial records, and proprietary business knowledge—has become increasingly vulnerable to interception and misuse. As a result, organizations must adopt robust security measures and encryption technologies to safeguard their communications and maintain trust with their stakeholders.

Whether it's military, financial, medical, personal, etc.—sharing information over the Internet and social networks has become an urgent necessity that cannot be ignored. This is where the importance of steganography technology, which is concerned with maintaining the confidentiality of information by camouflaging it, comes into play. This technology, which is a unique process, allows us to hide a secret message inside another file, often an image known as a camouflaged image. After entering the secret information into that image, the resulting image is called a "stego image." The goal of this process is to not reveal the secret information contained in the original file, making it difficult or even impossible to distinguish between the original copy and the document containing the secret message. There are many ways to achieve this, the most prominent of which is the LSB technique, which relies on the least significant bit. However, despite its effectiveness, this method suffers from a major limitation, which is the small size of the stored . information. Therefore, in this research, we decided to adopt a method that combines secret information processing and LSB technology with the aim of increasing the size of the stored information while maintaining image quality and confidentiality. This pursuit of excellence truly demonstrates how important innovation is to protecting our privacy in today's connected world.

Keywords

Data Security; Steganography, Steganalysis, RGB, LSB, pixel, bit.

I.INTRODUCTION

Technology has achieved a qualitative leap that has affected all aspects of our world, including transactions and exchanges between sensitive sectors such as the military, financial, medical, etc. While this digital technology serves most transactions in an amazing way, as the user achieves a profit for time, effort, and money, it remains a breeding ground for corruption, theft, and espionage. The science of information confidentiality plays a crucial role in safeguarding sensitive private information. This science is divided into several branches, perhaps the most important of which are the science of encryption and the science of steganography. The science of encryption depends on making the information encrypted, and it is difficult for anyone to solve the code unless he has the key. The science of steganography depends on camouflage using a cover, usually an image.

In turn, there are several methods in steganography, including LSB, which depends on using the last bit of the pixel (the least influential) to include the secret information. The user of this method may observe that, despite its effectiveness in concealing information, it has certain drawbacks. The most significant of these is its limited storage capacity, which necessitates the use of multiple images to transmit a single message. This, in turn, heightens suspicions from potential adversaries and, to a lesser extent, compromises the image quality.

Among the researchers who exploited LSB in their own way, we find:

Cheng [9] proposed the reflection pattern substitution (IPS) LSB approach to improve the quality of stego pictures. This method combines the pre-embedding processing of the secret data with the post-embedding processing of the stego image. This technique allows the secret data to be swiftly included into the cover image. The results show that the quality of the stego image is superior to both the optimal LSB substitution method and the optimal LSB substitution method (OPAP). Mohammad and Russilawati [5] proposed the bit-inversion technique to improve the quality of stego pictures in color photographs. This method for hiding the widely used LSB information steganography provided two degrees of protection. The first stage is to use two colors, blue and green, rather than the three in the standard LSB.

Using an addition process between the image's LSB pixels and secret data, Orooba [10] introduced a novel and effective technique for information concealment. The secret data is extracted using two keys in the extraction process, strengthening the hiding and making destruction more difficult. Experimental results indicate that this approach is both secure and user-friendly. In the future, a light secret code encryption system will be created.

Margniloway [11] presented a data-hiding technique for grayscale photos that was based on a simple LSB approach. To improve the result, they divided the cover image into two parts: one for embedding and the other for reversing. They also included a few hidden components. The second half shows the parts after they have been flipped. After embedding, they improve the STEGO image quality using the optimum LSBs approach. Experimental results show that they perform better than the BLAM technique in terms of capacity and PSNR.

A novel method for adaptive data-hiding grayscale images was presented by Khodaei and Faiz [12]. Pixel value difference (PVD) and LSB substitution are the foundations of the strategy. According to experimental results, this method outperforms Wu et al., Yang et al., and Liu et al. in terms of hidden image capacity and quality. It also requires less time complexity. Additionally, the method is safe from SPAM and RS attacks. An adaptive approach utilizing LSB-M as the embedding method was presented by Faji et al. [13]. After determining the cover image edges, they added and altered the data. A local neighborhood analysis-based complexity measure is used to determine the image's secure location. When compared to similar adaptive methods, their approach performs better and yields higher PSNR values.

In order to create a distributed information hiding technique based on FPPD, a novel method for concealing secret information is introduced in [14]. This method enables the transmission of several secret data components across multiple cover photos. The reference pixel's value is altered by adding a scale function. If the secret data is larger than the cover image, an alternative cover image may be used. Compared to the original FPPD method, this method's PSNR is lower. This is because the reference point's value is altered by the scale function. Using a 3-bit XOR data hiding scheme, A unique XOR-based technique for data concealment in grayscale photographs was presented by Kamal Diporajkumar [15]. The maximum number of bits that may be utilized to hide data in this method is X*Y*3, with a temporal complexity of O(1) and X and Y standing for the image's rows and columns.

Three fundamental characteristics of steganography techniques are robustness, high capacity, and excellent transparency. The sender needs to take into account the priorities, as a single technique cannot fulfill all three of these requirements [16]. Therefore, the goal of the proposed method is to increase capacity while preserving good visual quality. This is demonstrated by contrasting the suggested approach with the steganography methods currently in use by Ching [9], Margniuli [11], and Khodayi and Faiz [12]. According to the findings, the suggested approach outperforms conventional techniques in terms of capacity and transparency.

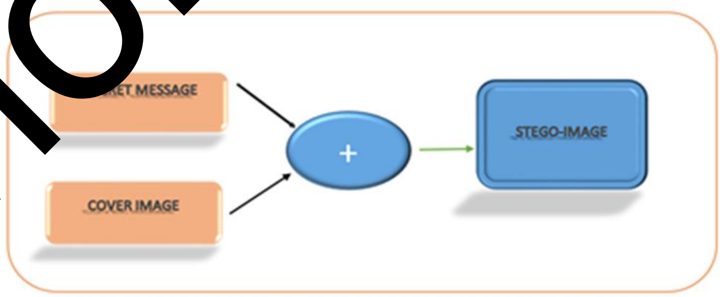

Fig 1: steganography system

The "proposed method" is explained by the way the research is structured.

We start by processing the data and adding it to the cover image. The secret information is then extracted by processing the data that was extracted from the Stego image.

The "Experimental Results" section discusses the findings. Lastly, the "Conclusion" section presents the conclusion.

As was already noted, the LSBs technique has a number of benefits, such as the high quality of the embedding picture and the simplicity of embedding and recovering secret information. However, it can be challenging to distinguish between the cover image and the embedded image. However, there are disadvantages to this method that cannot be overlooked. Firstly, the limited capacity of the embedded information forces the sender to use a large number of cover images, thereby raising doubts. Secondly, anyone can effortlessly extract information from the image. In this research, we proposed an improvement technique based on the LSBs method to enhance the capacity of secret information, while also reducing the complexity of information extraction for those unfamiliar with this method. In this section, our technique is explained and the results and conclusions are presented.

Algorithm steps:

Embedding as follows:

We are processing the secret information using arithmetic operations and converting between numerical systems, as we will explain later.

We are using the LSB method to embed the processed information in a way that will be explained in detail later.

Extraction as follows:

We will use the LSB extraction method for the stego image and process it in a way that will be explained in detail later.

We will process the information extracted from the Stego image using arithmetic operations and conversion between numerical systems, which will be explained later.

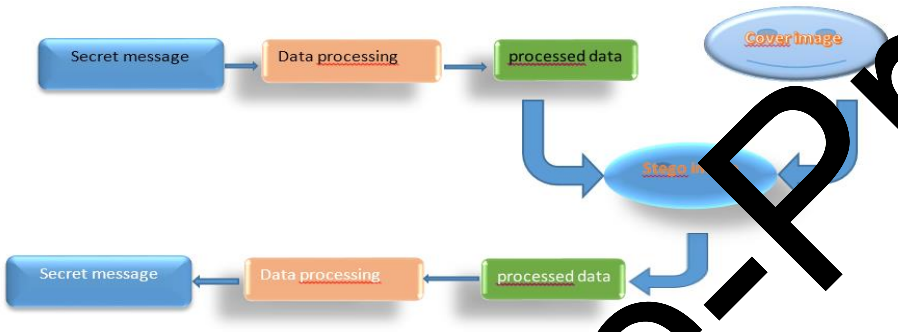

Fig 2 : Algorithmic steps of the proposed method

II. proposed method

The proposed methodology comprises two phases: the extraction phase and the embedding phase.

The embedding phase is hence subdivided into two components:

In the initial segment, we analyze the confidential information, as previously stated, through conversions between binary and decimal numeral systems and various computations.

The outcome is concealed within the least significant bits of the cover picture pixels instead of simply replacing them with secret bits.

The computations involve determining the quotient, remainder, multiplication, and addition, respectively.

The calculations and conversions between binary and decimal number systems are employed to minimize the size of embedded data and substantially enhance capacity.

The quotient and remainder obtained from the division operations are preserved in the cover image.

The cover image is divided into three halves. The initial segment is utilized to incorporate the residual within the least significant bits of the pixels.

The second segment is utilized to include the second leftover into the least significant bits of the pixels.

The third component is utilized to incorporate the quotient into the least significant bits of the pixels.

The methods for safeguarding confidential information are outlined in the following subsections. Embedding algorithm.

The procedure for retrieving the concealed data adheres to the inverse technique of the embedding algorithm, commonly referred to as the extraction algorithm.

The mathematical processes and numerical changes vary based on the type of cover image, whether it is grayscale or color.

The image utilized in the suggested methodology is delineated as follows:
Let I = {P1,..., PN} denote a collection of pixels constituting a grayscale image.
Each pixel comprises eight bits.

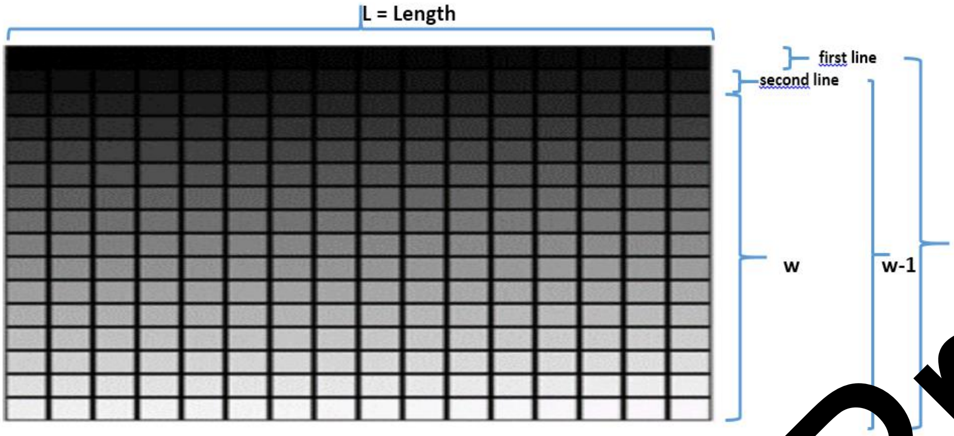

Fig 3 : Example of grayscale-image

|Pi| = 8 bits, Pi = {b1, ..., b8}, bj e {1, 0}. (3) The image size is calculated as follows

N = L × W. (4)

where L and W are the length and width of the image respectively. Let M be the secret data and N be the length of the secret data M,M = {m1, m2, ..., mn}, where mi e {1, 0}.

L = 282 pixels, W = 179 pixels

N= L*W =282*179 = 50478

picture 1 : Amir Abdelkader

- Let any RGB image consist of a set of pixels I = {P1, ..., PN}. Each pixel consists of 24 bits.

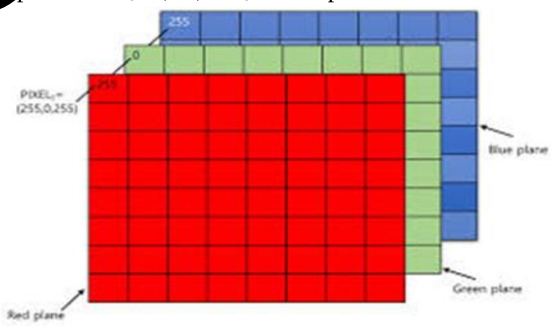

Fig 4 : Example of RGB IMAGE

|Pi| = 8 bits, Pi = {b1, ..., b8}, bj e {1, 0}. (3) The image size is calculated as follows

N = 3 *L × W. (4)

Let L and W represent the image's length and width, respectively. Let M be the secret data, and N is the length of the secret data. M,

M = {m1, m2,..., mn}, where mi e {1, 0}.

The maximum hiding capacity of frame I, denoted by h, can be calculated in terms of bits as follows:

L = 148 pixels, W = 148 pixels

N= L*W =148*148 = 21904

picture 2 : Colored image of a Bedouin woman

2.1 The embedding process

In the embedding process, the input is a grayscale or RGB color cover image and a string of secret data to be sent, whether it is an image or text message.

The output is a STEGO image.

Let's assume that L and W are the length and width of the image in which we want to embed the secret information, respectively (scale here is pixels), and M is the secret message.

M is a binary string composed of 0 and 1. This string is converted to decimal, resulting in the number D.

- In the case of a grayscale cover image

Picture3: Grayscale cover image

1. We divide D by L, the remainder is R, and the result is Q.
D DIV(L) = Q;; (D) MOD(L) = R.
2. We convert the remainder R from decimal to binary to give us Rb.
3. We include the remainder Rb in the first line; of course, R < L because (D)MOD(L) = R.
4. We divide Q by L; the remainder is R1, and the result is Q1 .
Q DIV(L) =Q1 ; (Q)MOD(L) = R1 .

We convert the remainder (R1) from decimal to binary to give us Rb1.

Q DIV(L) = Q1 ; (Q) MOD(L) = R1.

We convert the remainder R1 from decimal to binary to give us Rb1. We include the remainder Rb1 in the second line. Of course, R1 < L because (Q)MOD(L) = R1.

We convert the result Q1 from decimal to binary to give us Qb.

We include Qb starting from the third line until the line number "W" i.e., Q <= L * (w - 2).

Note: The bit value (0 or 1) in the LSB for each pixel is included in order.

Picture 4: Stego- grayscale image

- In the case of the cover image being an RGB color image

Picture 5 : Algiers (RGB-cover image)

1. We divide D by 3 * L. The remainder is R, and the result is Q.

(D) DIV(3*L) =Q ; (D) MOD(3*L) = R.

2. We convert the remainder R from decimal to binary to give us Rb .
3. We include the remainder Rb in the first three lines; of course, R < 3*L because (D)MOD(3*L) = R.
4. We divide Q by 3 * L. The remainder is R1 and the result is Q1.
   (Q) DIV(3*L) =Q1 ; (Q) MOD(3*L) = R1.
5. We convert the remainder R1 from decimal to binary to give us Rb1.
6. We include the remainder Rb1 in the SECOND three lines; of course, R1 < 3*L because ((Q)MOD(3*L) = R1).
7. We convert the result Q1 from decimal to binary to give us Qb.
8. We include Qb starting from the seventh line until the last line. Q1 <= 3*L *(w -2).

Picture 6 : Sea (stego –color image)

2. 2 Extraction Algorithm

The type of stego image will be important to recovering confidential data, whether it is grayscale or colored.

- In case of gray stego image

The image is divided into three parts: the first part is the first line, the second part is the second line, and the third part starts from the third line to the last line.

1. The first part:
- We extract the LSB bits of the first line in order to give us a series of binary numbers, which are Rb.
- We convert Rb from binary to decimal to give us the number R.
2. The second part:
- We extract the LSB bits of the second line in order to give us a series of binary numbers, which are Rb1.
- We convert Rb1 from binary to decimal to give us the number R1.
3. The third part:
- We extract the LSB bits starting from the third line to the last line in order to give us a series of binary numbers, which are Qb.
- We convert Qb from binary to decimal to give us the number Q1.
- We perform the following operation: ((L * Q1 + R1)*L+R) = D.
- We convert the number D from decimal to binary to give us a series of 0 and 1, which is M, our secret message.

- In case of color stego image

The image is divided into three parts: the first part is the first three lines, the second part is the second three lines, and the third part starts from the seventh line until the last line.

1. The first part:
- We extract the LSB bits from the first three lines(1,2,3) to give us a series of binary numbers, which is Rb.
- We convert Rb from binary to decimal to give us the number R.
2. The second part:
- We extract the LSB bits from the second three lines (4,5,6) to give us a series of binary numbers, which is Rb1.

We convert Rb1 from binary to decimal to give us the number R1.

3. The third part:
- We extract the LSB bits starting from the seventh line until the last line to give us a series of binary numbers, which is Qb.
- We convert Qb from binary to decimal to give us the number Q1.
- We do the following operation: (Q1 * 3* L + R1)*L+R = D.
- We convert the number D from decimal to binary to give us a series of 0 and 1, which is M, our secret message.

III. Experimental results

The performance evaluation of the proposed method is based on the results of extensive experiments.

The four standard grayscale images "Emir Abdelkader", "Wolf", "Forest", and "Archaeology" and the color images "Bedouin", "Petra", "Algiers", and "Sea" To ensure a comprehensive evaluation, the experiments utilize cover images of varying sizes and types.

The data included in the cover images are the processed confidential data and not the direct confidential data.

The programming language used in the current experiments is MATLAB 9.2.

The capacity and visual quality of the stego image are the two primary metrics used to estimate the performance evaluation of the suggested method. Capacity, which is measured in bits per pixel (bpp), is the maximum number of secret data bits that can be embedded in a pixel of the cover media. It gauges the method's effectiveness based on how much data it can incorporate. The higher the capacity, the better the evaluation.

We compare the quality of the stego image with the original image, the cover image, using the PSNR coefficient.

The higher the quality, the weaker the suspicion ratio, i.e., the image does not attract attention.

IMAGE NAME	SIZE N=length*width (by pixel)	Maximal size secret message using (by bit)		The ratio of the secret message embedded in the proposed method to the classical method "LSB"
		By classical method"LSB "	By proposed method	
Emir Abdelkader	50478	50478 bit	3969440459 bit	78637
Wolf	50512	50512 bit	[illegible]	106188
Forest	50400	50400	[illegible]	88930
Archaeology	50530	[illegible]	4796447099	94922

Table 1 Experimental Results for gray images

IMAGE NAME	**SIZE N=length*width (by pixel)**	**[illegible] (by bit)**		**The ratio of the secret message embedded in the proposed method to the classical method "LSB"**
		By classical method " LSB "	**By proposed method**	
Bedouin woman	**[illegible]**	**65712**	**1419926799**	**21608**
Petra	**[illegible]**	**119880**	**8621226899**	**71915**
Algiers	**151470**	**151470**	**13203917000**	**87171**
the sea	**151272**	**151272**	**10432724543**	**68966**

Table 2 Experimental Results for color images

3.1 Comparison between cover-image and stego-image using secret message M

Secret message M

"Science is the greatest collective endeavor. It contributes to ensuring a longer and healthier life, monitors our health, provides medicine to cure our diseases, alleviates aches and pains, helps us to provide water for our basic needs – including our food, provides energy and makes life more fun, including sports, music, entertainment and the latest communication technology. Last but not least, it nourishes our spirit.

Science generates solutions for everyday life and helps us to answer the great mysteries of the universe. In other words, science is one of the most important channels of knowledge. It has a specific role, as well as a variety of functions for the benefit of our society: creating new knowledge, improving education, and increasing the quality of our lives.”

From the United Nations Educational, Scientific and Cultural Organization (UNESCO).

Picture7:sphinx (gray cover– image)

Picture8 : sphinx (gray stego –image)

Comparison between gray cover-image and gray stego-image

Picture9: Petra (color cover –image)

Picture8: Petra (color stego –image)

Comparison between cover-image and stego-image

The statistic typically employed to assess the distortion between the original image and the altered image is PSNR (peak signal-to-noise ratio). The measure is based on the mean square error (MSE), with a higher MSE indicating greater distortion in the image. If the resemblance between the two photos suggests that MSE = 0, this can be determined using the subsequent formula:

$$MSE = \frac{1}{\mathrm{L} * \mathrm{W}} \sum_{i=1}^{i=L} \sum_{j=1}^{j=W} [IM(i,j) - IM'(i,j)]^2$$

L represents the length of the image, whereas W denotes the width of the image. IM(i,j) and IM'(i,j)xp represent the pixel values of the pictures under comparison. A greater MSE indicates a higher degree of degradation.
The PSNR is computed using the following formula:

$$PSNR = 10 \log_{10} \frac{(255)^2}{MSE}$$

Where $xmax$ is the maximum luminance and MSE defines the mean square error calculated between the pixels of two images to be compared. A PSNR value equal to infinity (∞) corresponds to two perfectly identical images. It decreases as a function of distortion and therefore relates the mean square error to the maximum energy of the image.

COVER-IMAGE NAME	SIZE OF OVER-IMAGE N=length*width (by pixel)	SIZE OF MESSAGE EMBEDDING (by bit)		PSNR	
		By classical method " LSB "	By proposed method	By classical method " LSB "	By proposed method
Emir Abdelkader	50478	50478 bit	14235077 bit	56.38	56.39
Wolf	50512	50512 bit	16066994 bit	60.91	60.89
Forest	50400	50400 bit	15030598 bit	58.45	58.4[illegible]
Archaeology	50530	50530 bit	14703627 bit	62.37	62.36

Table3 Experimental results PSNR value for Gray images

COVER-IMAGE NAME	SIZE OF OVER-IMAGE N=length*width (by pixel)	SIZE OF MESSAGE EMBEDDING (by bit)		PSNR	
		By classical method " LSB "	By proposed method	By classical method" LSB "	By proposed method
Bedouin woman	65712	65712	[illegible]	63.85265	64.10903
Petra	119880	119880	32149707	57.97435	57.81617
Algiers	151470	[illegible]	44722848	60.83018	61.71802
the sea	151272	151272	39727509	59.14728	59.28424

Table 4 Experimental results PSNR value for RGB images

Whether the cover image is gray or colored, our method, which doubles the processing of the secret information, yielded results that more than doubled the capacity of the secret messages, surpassing 200 times the capacity of the method we proposed in our previous study. As for comparing using the classic LSB method, we notice that the capacity of the stored secret messages was doubled several times according to the length and width of the image, and it may exceed 50,000 times the capacity of the stored secret messages.
The image quality is almost identical to the storage quality using the classic LSB method.
The confidentiality of the information stems from the fact that, unlike the classic LSB method, our method involves double processing of the extracted information from Stego Image to obtain the secret message, making it more confidential.

IV. CONCLUSION

This paper presents an efficient technique for concealing data bits.

According to prior study, the processing of confidential information is doubled. The data is handled through conversions between numerical systems (binary and decimal) and arithmetic operations.
The cover image, whether of being gray or colored, is segmented into three sections.
Two components: one to encompass the initial remainder and the other to incorporate the subsequent remainder of the processed information's length and the cover image's length.
The third component comprises the quotient of the length of the processed information to the length of the cover image.
The embedding technique incorporates the embedding of the remainder and the outcome instead of directly encoding the secret message as in the traditional LSB method.
In the secret information extraction approach, we extract the final bit of each pixel sequentially from the first segment, then the second segment, and subsequently the third segment.
We obtain the first residual, the subsequent remainder, and the quotient. Subsequently, by employing binary and decimal conversions together with arithmetic processes as previously delineated, we retrieve the confidential information.
The experimental results indicate that the current method markedly enhances the capacity for hidden communications, addressing the primary concerns and limitations of the traditional LSB method, while also elevating the quality of the embedded image. Individuals employing the LSB approach, without the requisite knowledge to process the information, will have challenges in extracting data because to the unclear results obtained.

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